Analysis of Rawinsonde Spatial Separation for Space Launch Vehicle Applications at the Eastern Range

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Background

- Space launch vehicles are sensitive to tropospheric winds during ascent
  - Structural loads
  - Optimizing trajectory
- Measurements from high-resolution (HR) rawinsondes are used in vehicle evaluations in both design and day-of-launch (DOL)
- Rawinsondes have several limitations which can affect launch vehicle evaluations on DOL
  - Time to measure data to 18 km
  - Downrange drift
- Downrange drift can result in measuring an environment different from what the vehicle will experience during ascent
- Statistically determine the drift distance away from the Eastern Range (ER) as a function of season and annually
- Introduce a method to generate a vertically complete profile that better represents the ascent environment if long downrange drift distances occur with HR rawinsondes on DOL

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Data Sources

- ER uses a specially designed balloon, Jimsphere, that reduces sonde oscillation to improve measurement accuracy
- HR wind measurements are in 30 m increments
- Jimsphere maintains constant volume which limits altitude coverage up to ~18-20 km

- MSFC Natural Environments Branch (NEB) maintains data archive of HR profiles
  - 2335 profiles (1696 from RADAR tracked; 839 from GPS based)
  - Period of Record from 1989-2015

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Analysis

- All balloon data had to reach a minimum of 15.2 km
- Divided data into seasons
  - 733 winter; 792 transition; 604 summer
- Determined downrange distance
  - Approximated the balloon distance by calculating the change of position (displacement) throughout ascent using the wind speed, wind direction and rise rate data
- Used the maximum downrange distances reached from each profile and determined the empirical cumulative probability distribution from all profiles seasonally and annually

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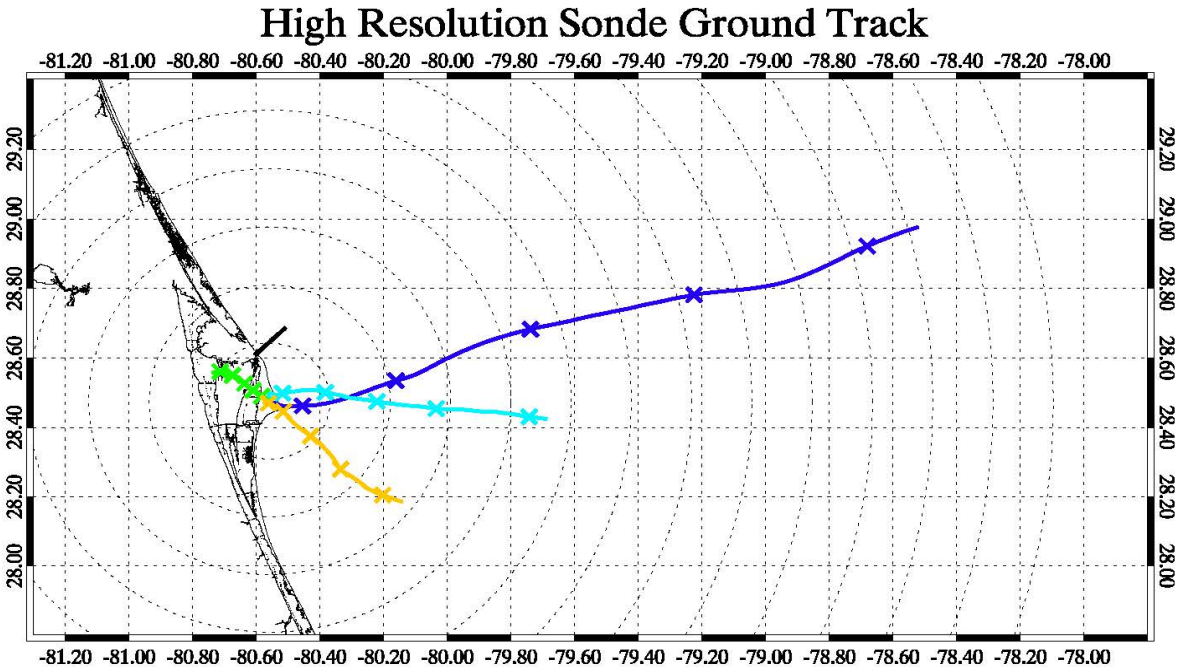
Analysis



- Selected profiles representing the 50 percentile downrange distance of HR rawinsondes for winter (cyan), summer (green), and transition (gold) along with the database maximum (blue). Solid black line represents the STS-117 ascent trajectory up to 23 km. The “X” in the profiles represents 3 km altitude intervals

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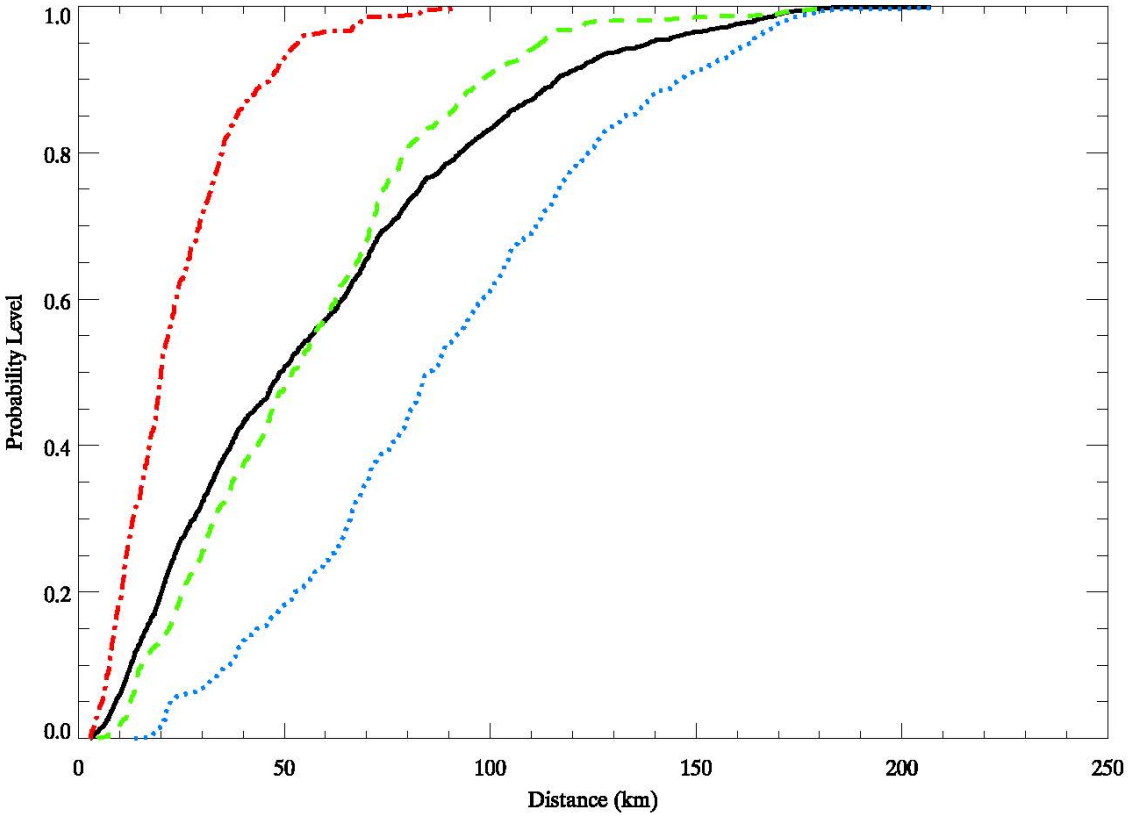
Analysis

- Maximum downrange drift exceeded 200 km in winter
- Results are consistent with the climatological upper-level wind environment over ER
  - Stronger winds in the winter result in further downrange drift
  - Lighter winds in the summer result in less horizontal drift



Empirical cumulative probability distributions of maximum downrange distance for winter (blue), transition (green), summer (red) and annual (black)

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Impact to DOL operations

- The long downrange distances the balloons travel during DOL operations are due to strong upper-level winds
- Downrange measurements from HR rawinsonde drift may not be representative of the ascent environment the vehicle will experience on DOL
- The NASA KSC vertically pointing Tropospheric Doppler Radar Wind Profiler (DRWP) better represents the upper-level environment the vehicle may experience during ascent
  - Tropospheric profiles from 2-18 km every 5-min
  - New replacement system installed 2014
- Effective vertical resolution (EVR) of DRWP is ~450 m whereas HR rawinsondes are ~200 m
- Limited altitude coverage and different EVR can limit the use of the DRWP during DOL operations to a situational awareness tool and not included in trajectory and loads calculations

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PRESTO

- MSFC/NEB has developed the Profile Envision and Splicing Tool (PRESTO) to generate the best spatial and temporal representation of the tropospheric environment for launch vehicle DOL operations and assessments
  - Splices and smooths all the ER data sources to generate a vertically complete atmospheric profile
  - Also includes visualization to compare input sources with the PRESTO generated profile

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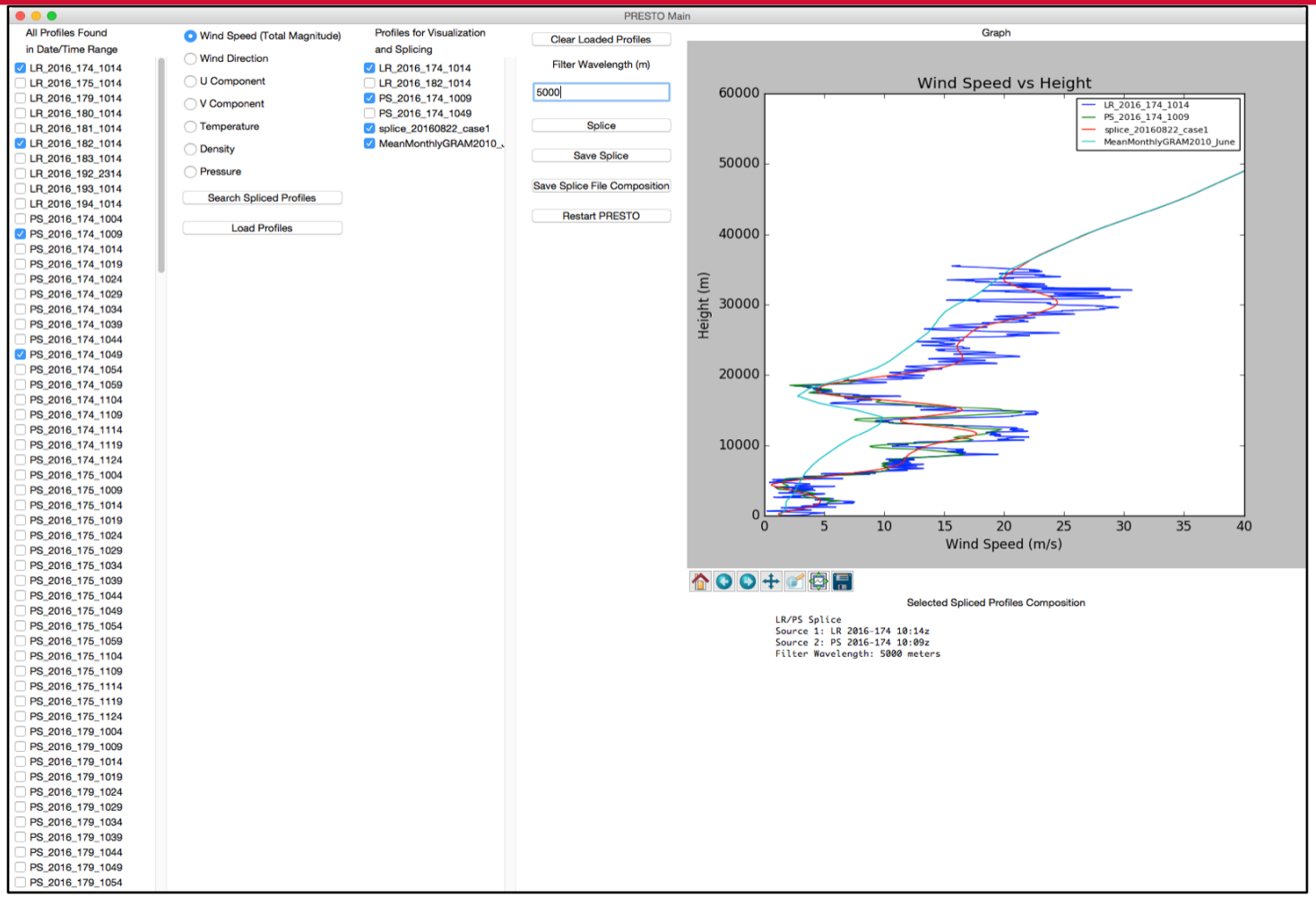
PRESTO



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Summary

- Spatial separation of HR rawinsonde data is directly correlated with climatological tropospheric wind environment over ER
  - Stronger winds in the winter result in further downrange drift
  - Lighter winds in the summer result in the less horizontal drift during ascent
- Maximum downrange distance can exceed 200 km during winter months
- Data could misrepresent the environment the vehicle will experience during ascent
- PRESTO uses all available data sources to produce the best representative, vertically complete atmosphere for launch vehicle DOL operations
- Capability planned for use by NASA Space Launch System vehicle's first flight scheduled for Fall 2018

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AMS Theme: Observations Lead the Way

- Space launch range community would greatly benefit from rapid cycle (5-10 min), full tropospheric/lower stratospheric (0-30 km) atmospheric measurement capability

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